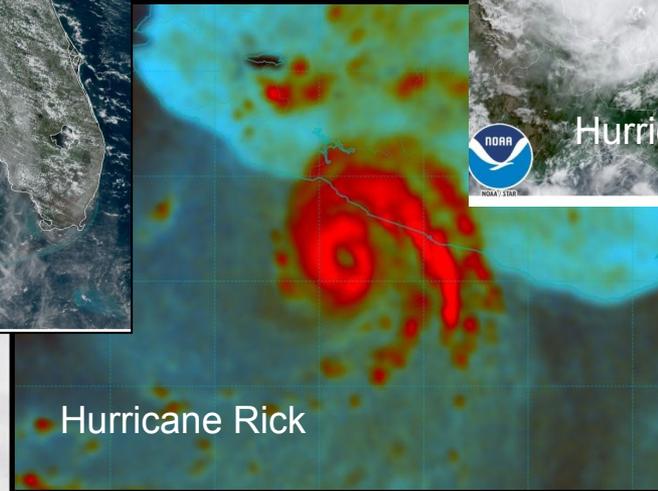
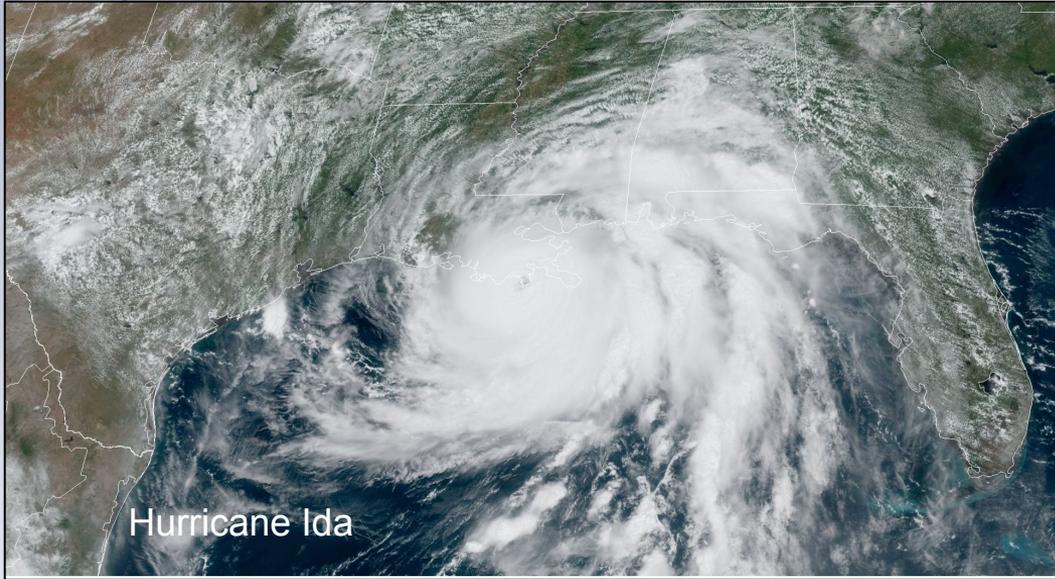
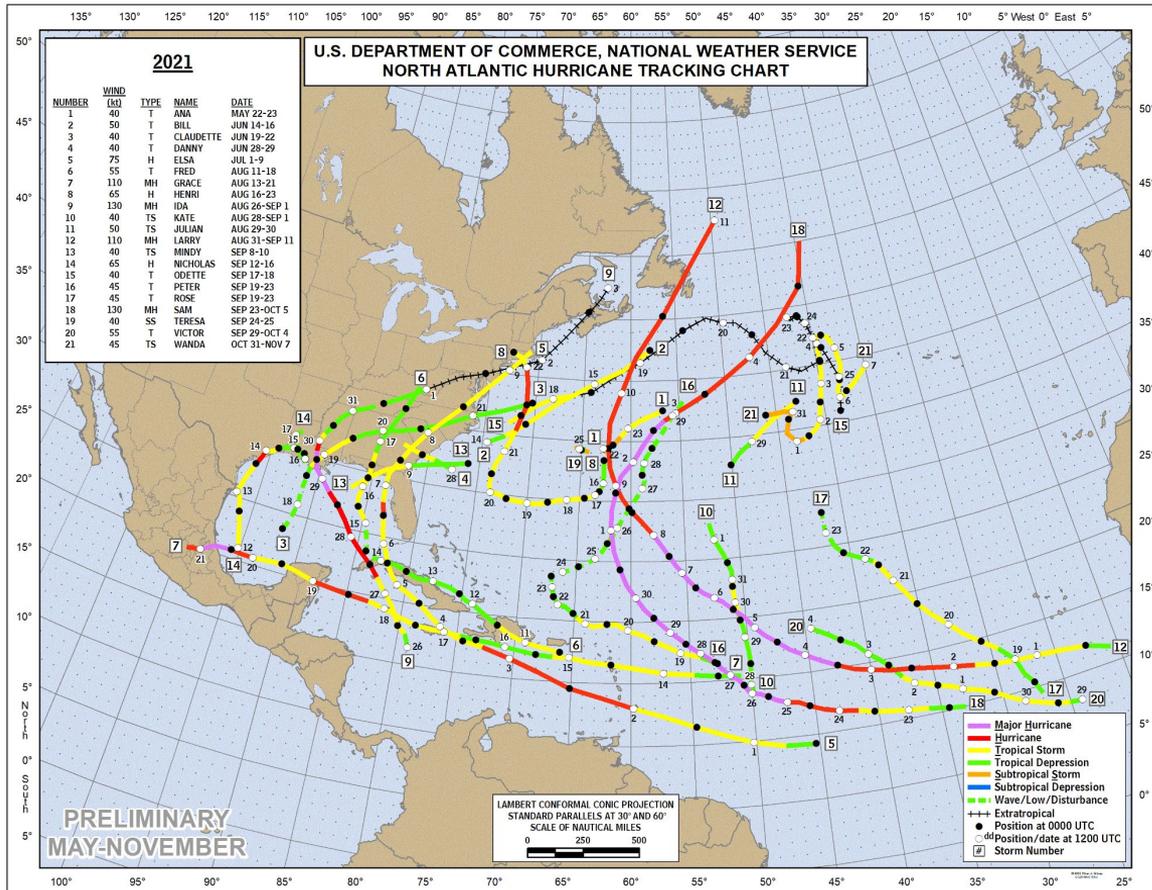


2021 Hurricane Season Summary



Eric Blake & Michael Brennan
NOAA/NWS/NCEP National Hurricane Center

2021 Atlantic Season Summary



- 21 named storms
 - 9 with peak intensity < 50 kt
- 7 hurricanes (**4 major**)
- ACE: About 50% above the long-term average
 - Sam and Larry accounted for ~ 60% of 2021 ACE
- 2020 & 2021: 51 named storms, 21 hurricanes, 11 major (!)

Seasonal Impacts - Atlantic

- 8 U.S. landfalls
 - 6 Tropical Storms: Claudette, Danny, Elsa, Fred, Henri, Mindy
 - 2 Hurricanes: **Ida**, Nicholas
- Direct U.S. fatalities*: 71 (56 from Ida)
- Indirect U.S. fatalities*: 43
- Direct International fatalities*: 18 *Preliminary
- **\$75B** in U.S. damage from Ida (more than U.S. damage from the entire 2020 season)
- International impacts
 - Elsa (Barbados), **Grace** (Mexico, Haiti, DR, Jamaica, Cayman), Ida (Cuba), Larry (Canada)
- 10 systems had watches or warnings issued on the first advisory

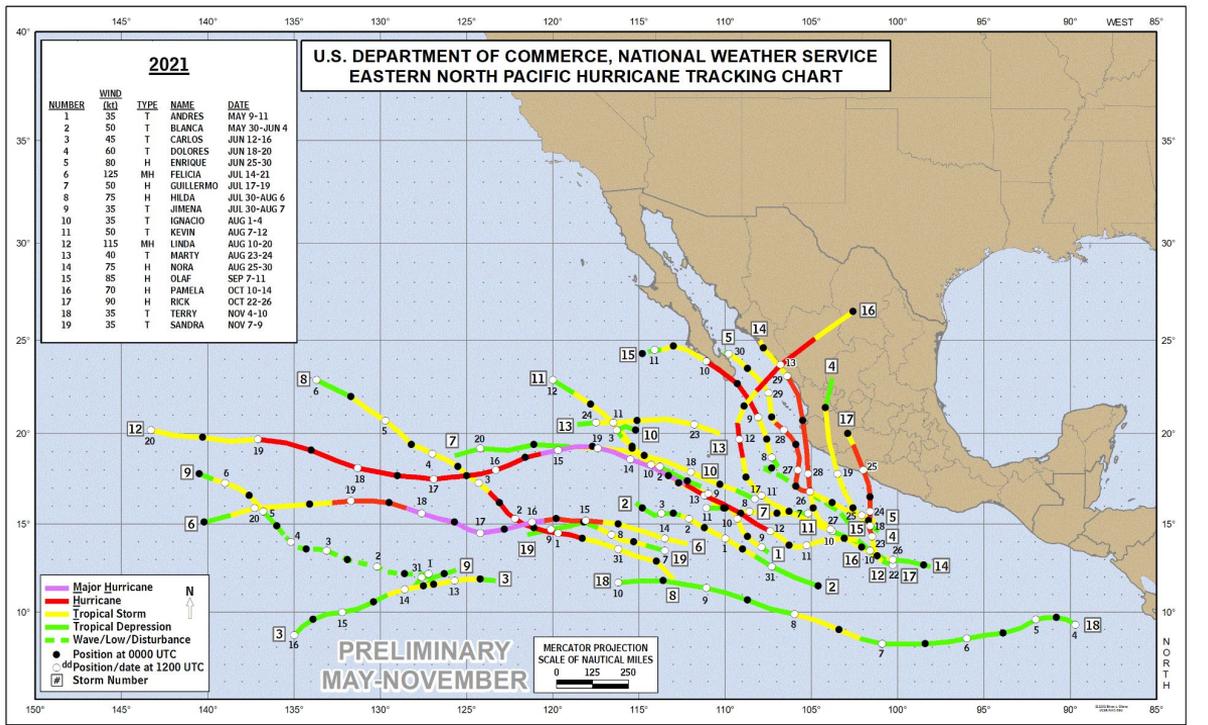


Image Courtesy AP



Image Courtesy Reuters

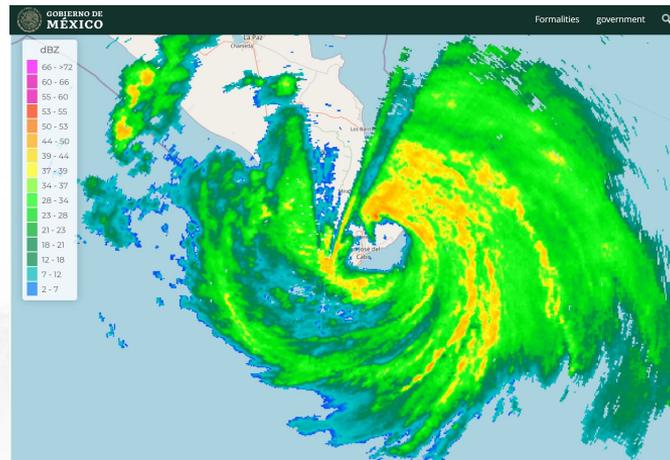
2021 Eastern North Pacific Season Summary



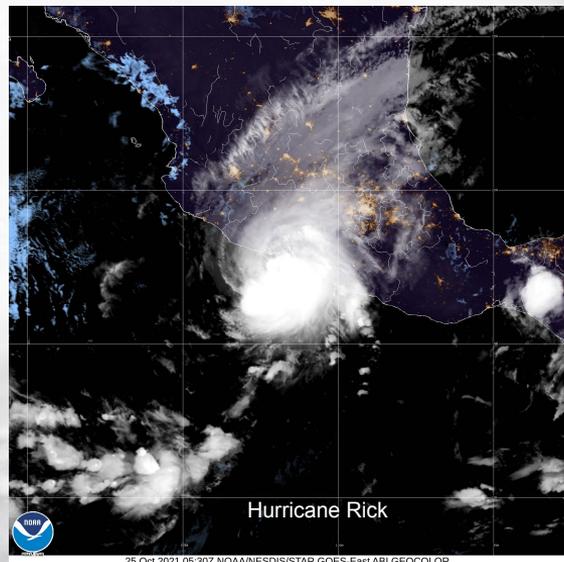
- 19 named storms
 - 7 with peak intensity < 50 kt
- 8 hurricanes (**2 major**)
- ACE: ~90% of average

Seasonal Impacts - East Pacific

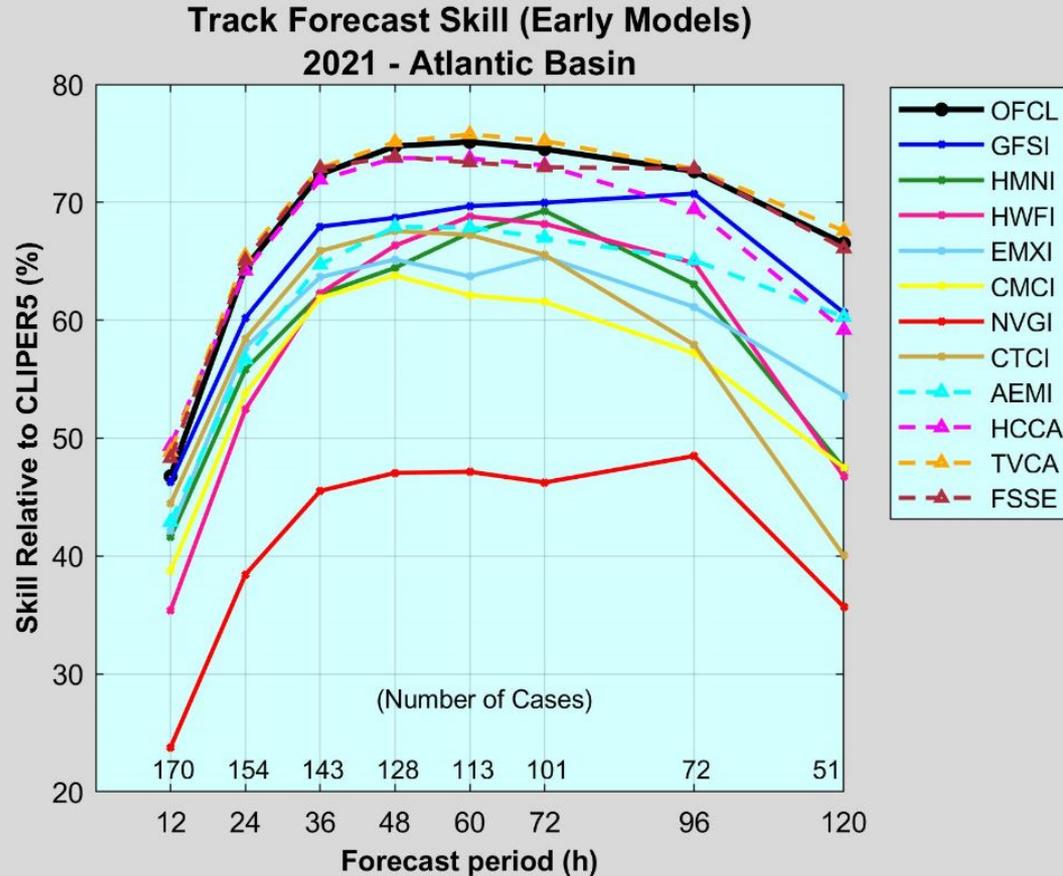
- 6 storms with impacts in Mexico
 - 4 hurricane landfalls: Nora (Jalisco), Olaf (Baja California Sur), Pamela (Sinaloa), Rick (Guerrero)
 - 1 TS landfall: Dolores (Michoacán/Colima)
 - Hurricane Enrique had direct impacts while remaining offshore
 - Direct Fatalities (preliminary):
 - Mexico: 10
 - U.S.: 2 (Texas from Pamela rainfall)



Radar imagery of Hurricane Olaf at landfall courtesy of CONAGUA



Preliminary 2021 Verification - Atlantic Track

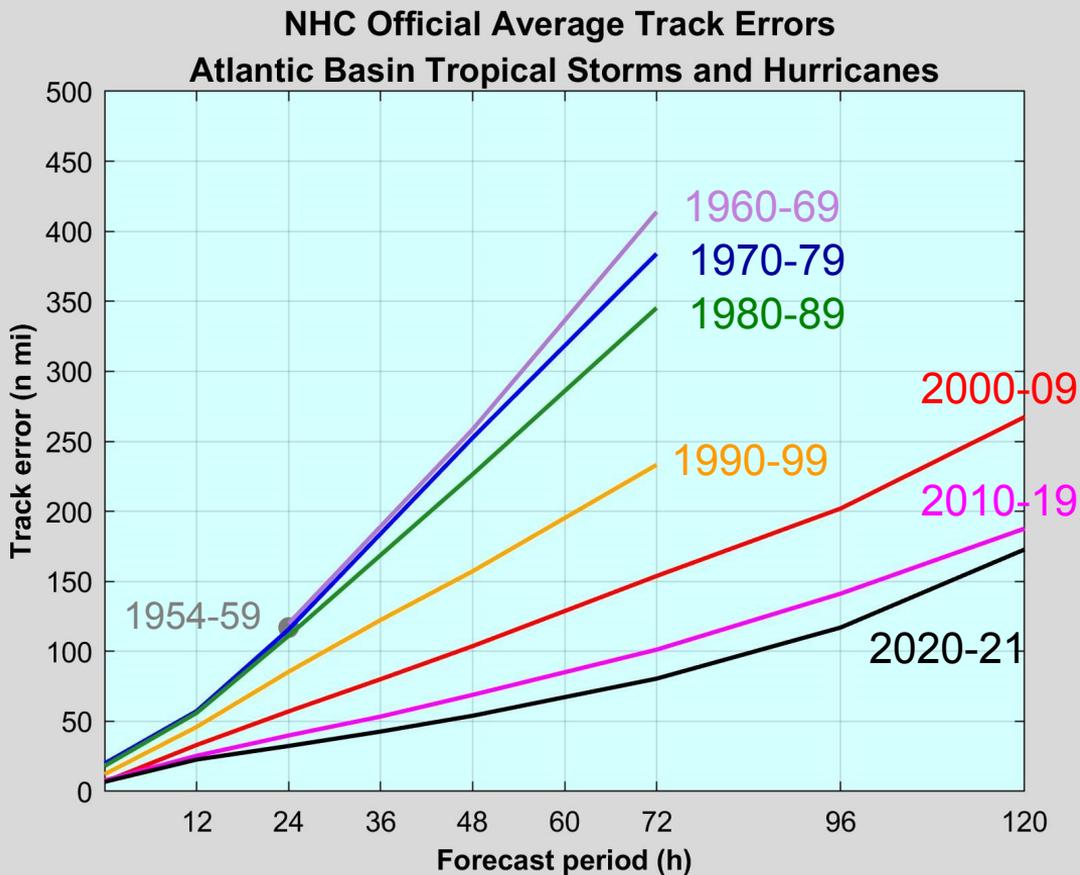


NHC forecasts were very skillful and near or better than the consensus aids

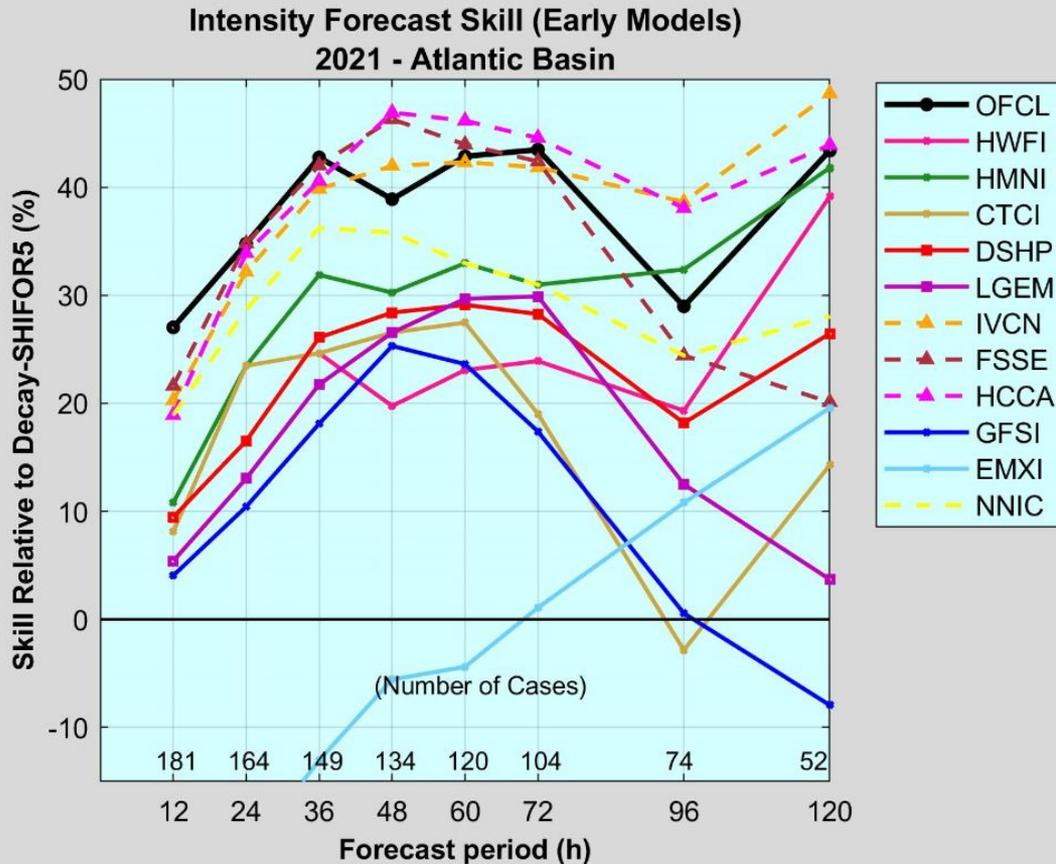
GFS was best individual model for track



Atlantic Track Error Trends



Preliminary 2021 Verification - Atlantic Intensity

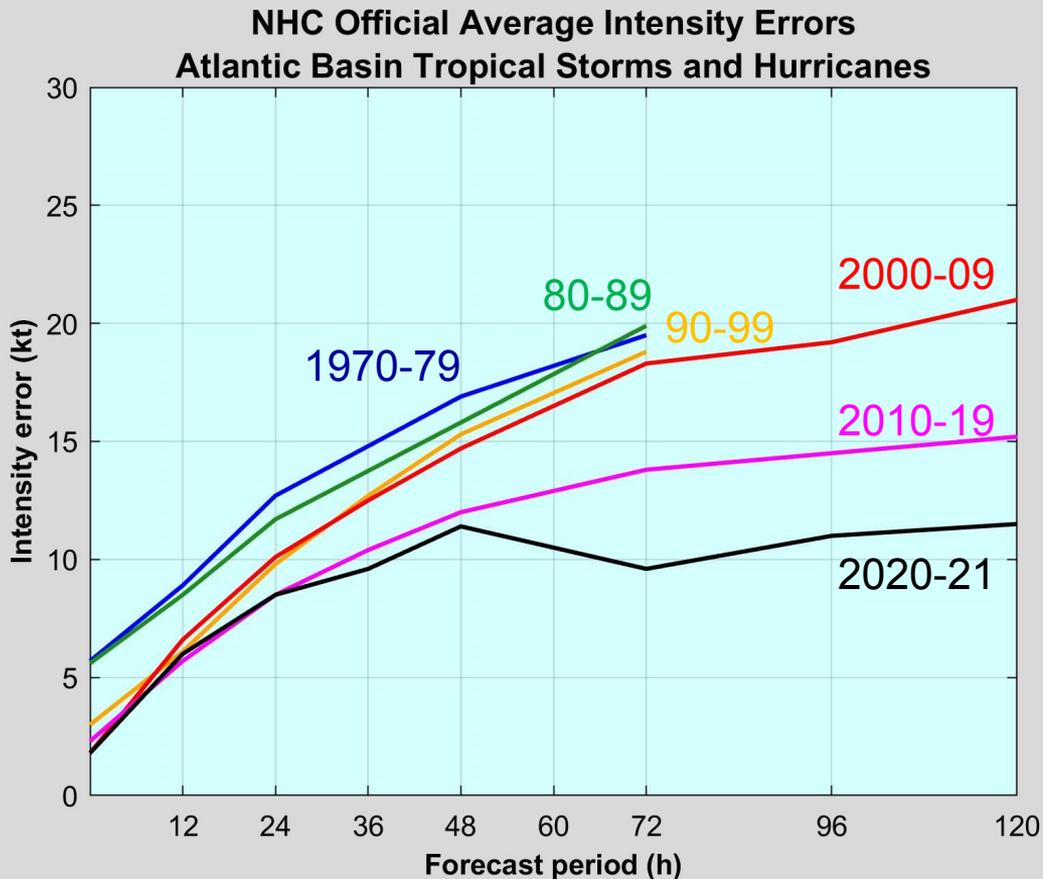


NHC forecasts were very skillful, as good as or better than the consensus aids

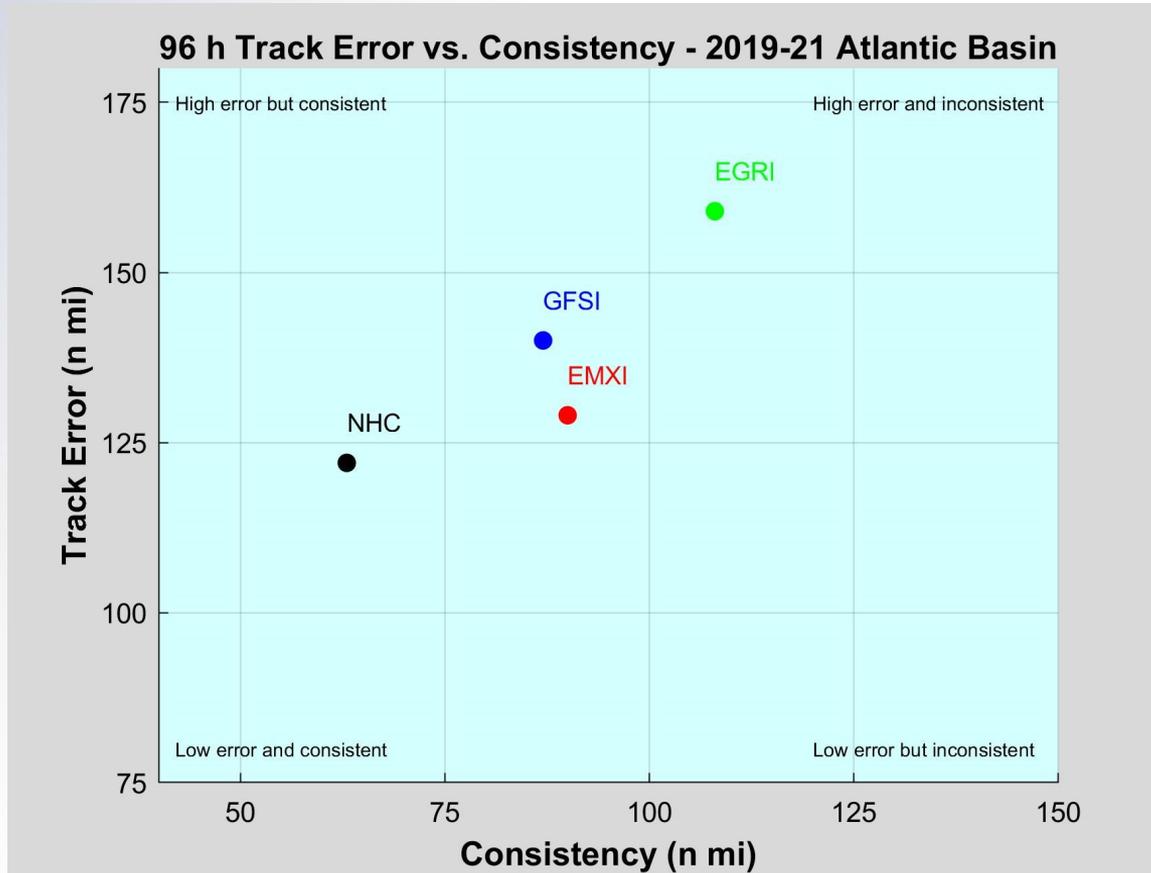
HMON (!) was best individual model, but all individual models well less than consensus aids



Atlantic Intensity Error Trends



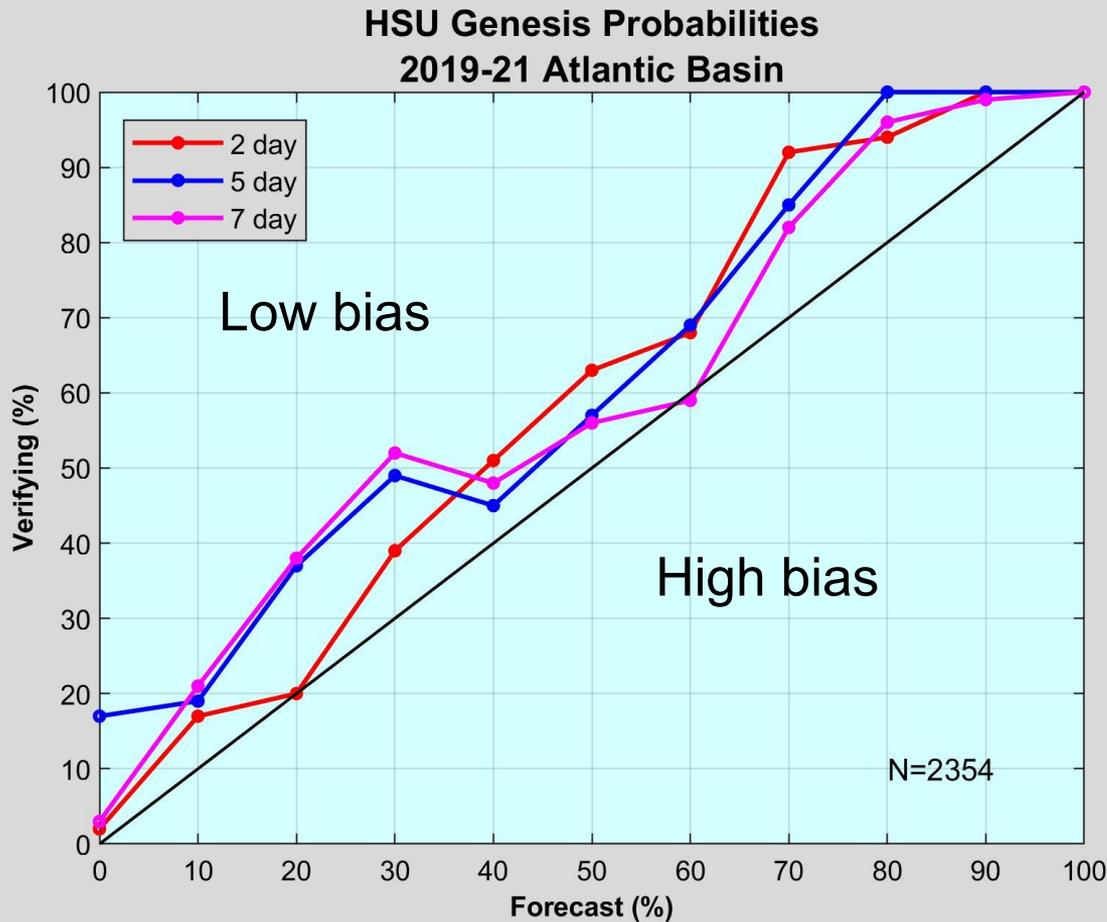
Are the forecasts consistent?



NHC forecasts lowest error and most consistent of any guidance



Atlantic Genesis Forecast Verification



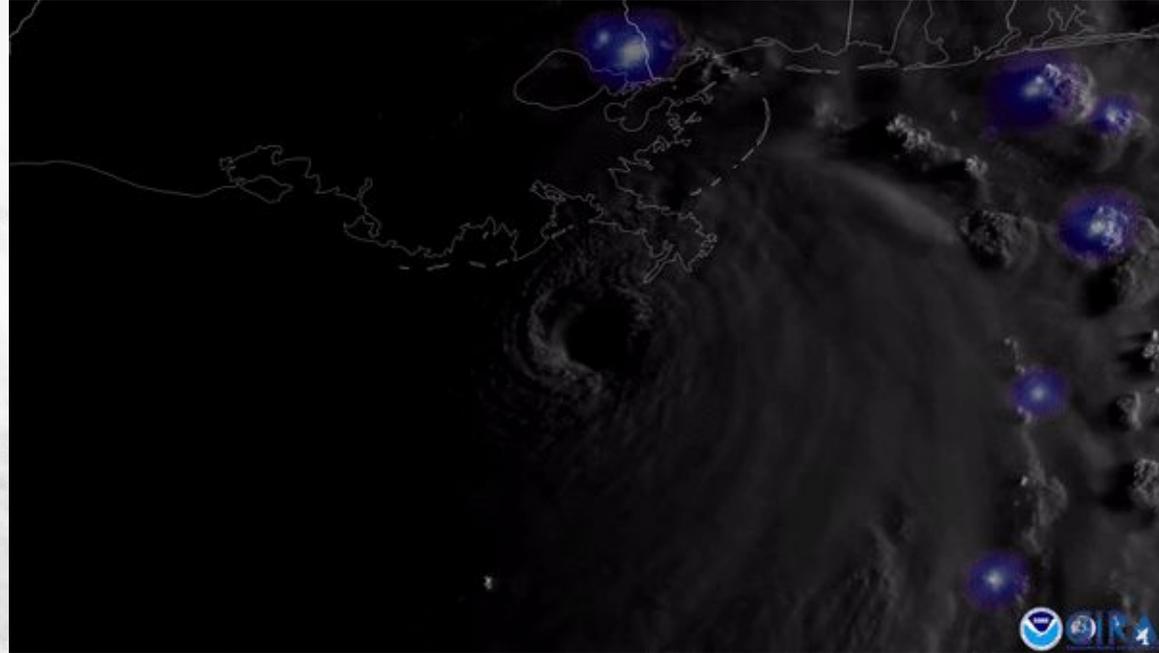
Forecast Challenges - Rapid Intensification

Atlantic 24 h changes

- Grace: 50 kt (60 -> 110 kt)
- Ida: 35 kt (35 -> 70 kt)
- Ida: 55 kt (75 -> 130 kt)
- Larry: 30 kt (80 -> 110 kt)
- Sam: 45 kt (75 -> 120 kt)

East Pacific

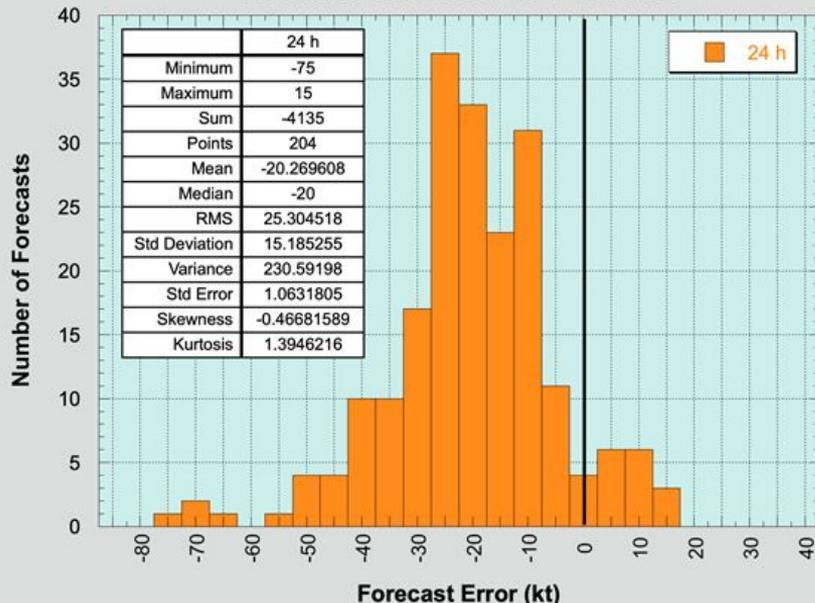
- Felicia: 35 kt (60 -> 95 kt)
- Linda: 35 kt (65 -> 100 kt)
- Olaf: 40 kt (40 -> 80 kt)
- Rick: 40 kt (35 -> 75 kt)



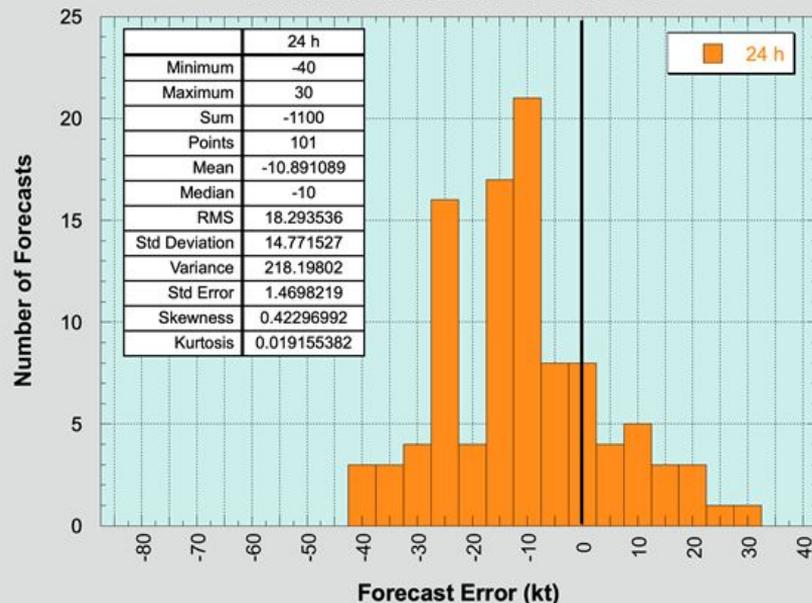
GOES-16 visible imagery and GLM data for Ida

Rapid Intensification Verification

**NHC Official Forecast
2015-17 AL/EP Combined
When RI Observed or Forecast**



**NHC Official Forecast
2020-21 AL/EP Combined
When RI Observed or Forecast**

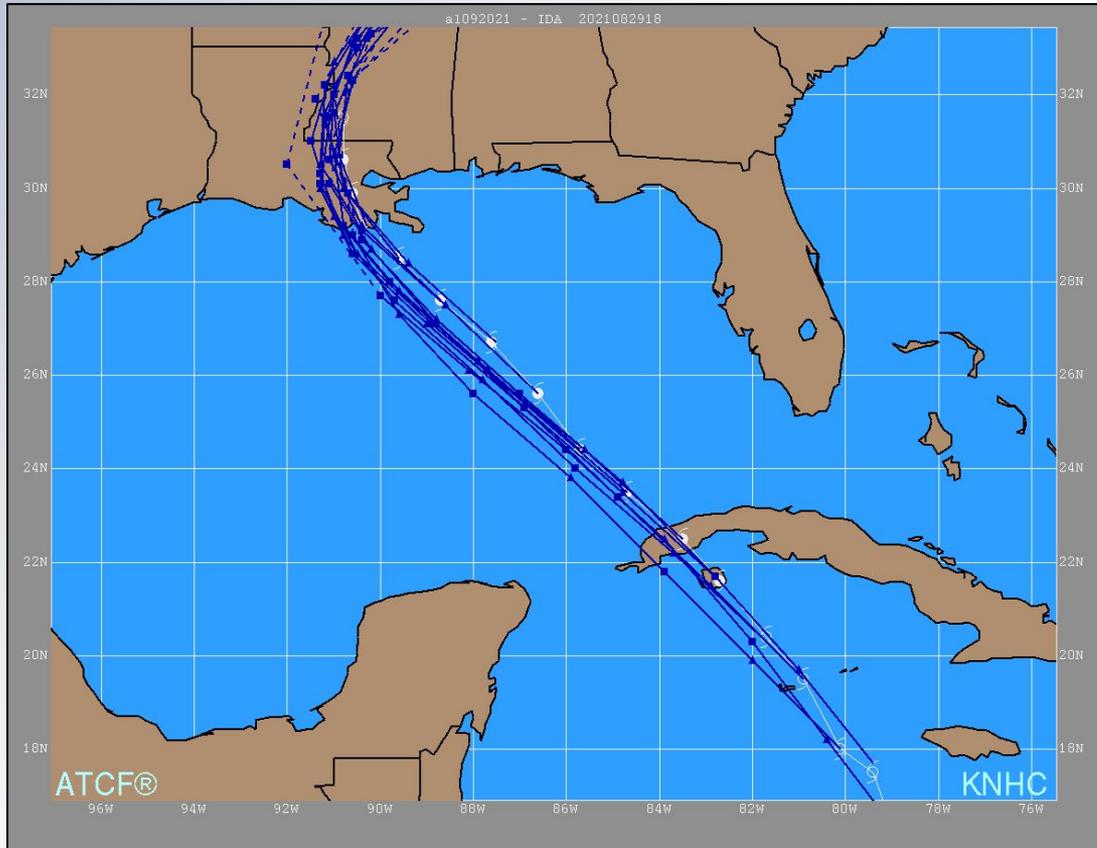


When rapid intensification observed or forecast, median NHC forecast has improved from -20 to -10 kt
Very large negative errors are gone and median/mode are now within the margin of error for estimating TC intensity

Positives

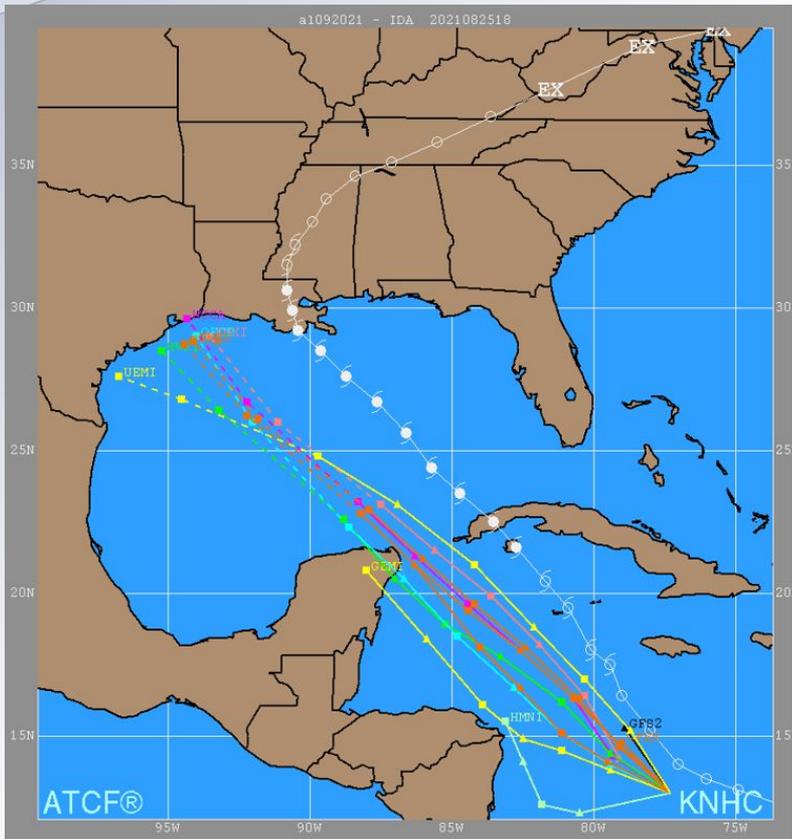
- Minimal (3) U.S. storm surge fatalities in 2020-2021 despite 8 landfalling U.S. hurricanes
 - 1 storm surge fatality in Ida
- Improvements in NHC forecasts during rapid intensification events
 - Very aggressive early forecasts for Ida indicated the potential for a major hurricane landfall in Louisiana from the first advisory
- Potential Tropical Cyclone Advisories providing more lead time for developing TCs
 - Average of 17 h of additional lead time for watches/warnings
- Improving watch/warning collaboration - exchange of grids, video-teleconference capabilities
- Developing remote ops capability strengthened NHC COOP

Consistency of NHC's Ida Track Forecasts

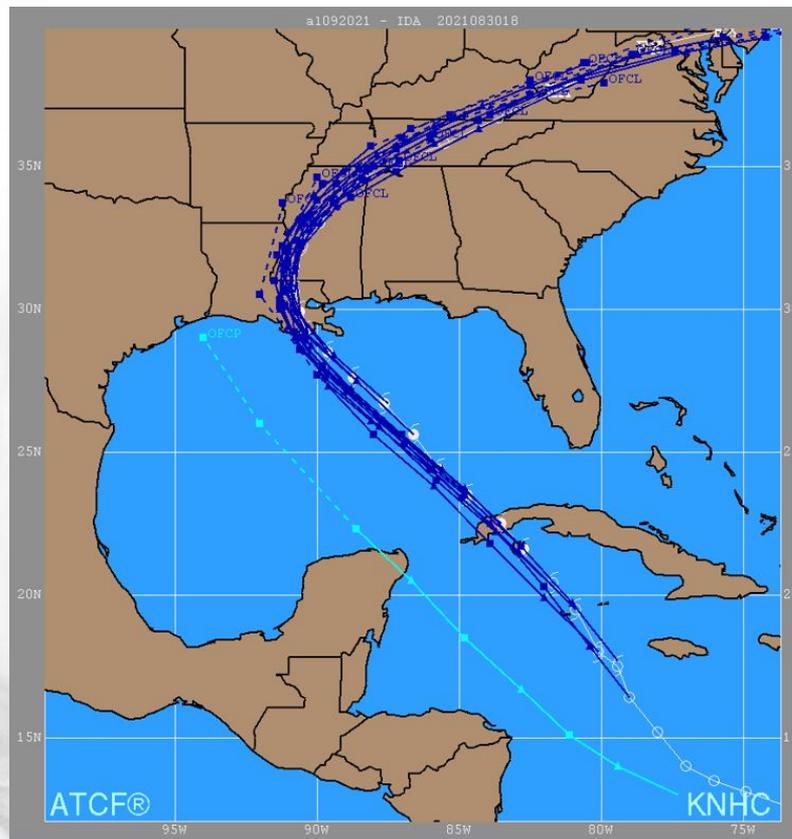


NHC track forecasts consistently showed Ida making landfall along the coast of southeastern Louisiana

Forecast Challenges - Pre-Genesis Ida Track Guidance

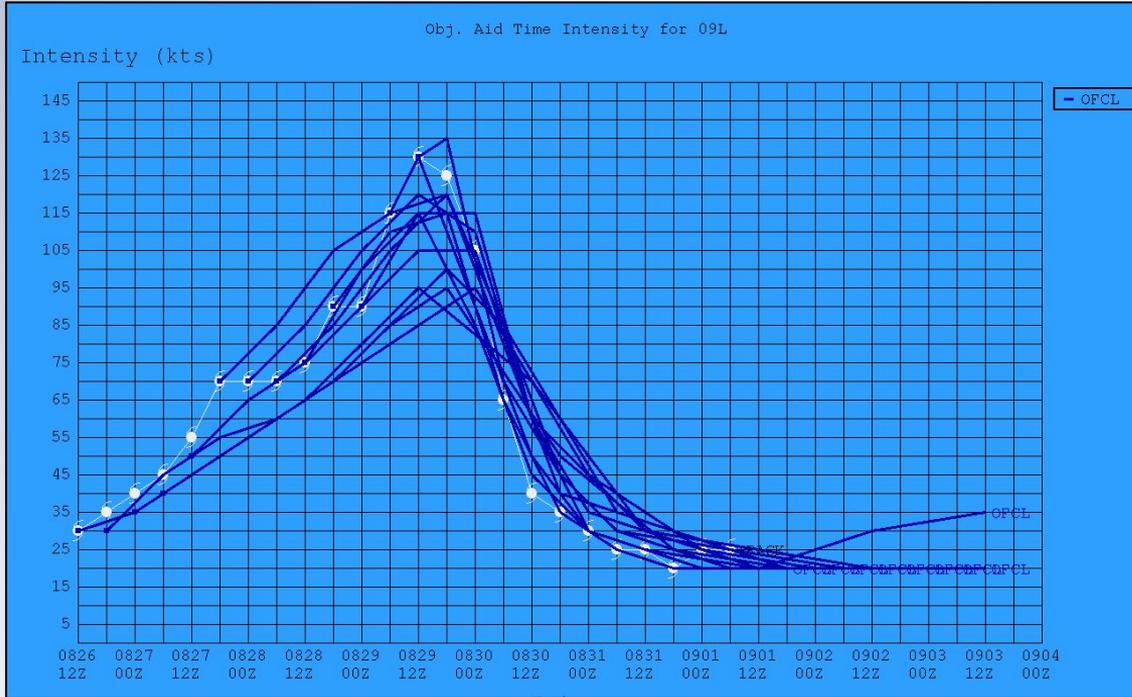


Pre-Genesis Ida Track Guidance 18Z 8/25



Pre-Genesis Ida Provisional Forecast and subsequent NHC Official Forecasts

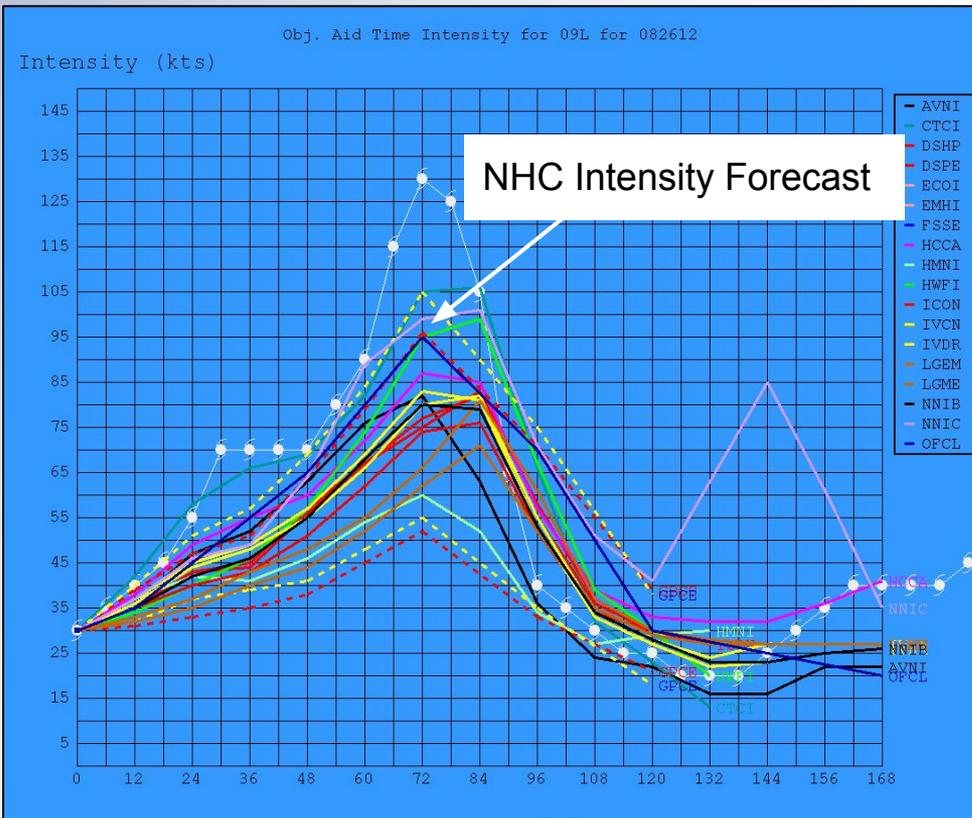
Consistency of NHC's Ida Intensity Forecasts



NHC's intensity forecasts consistently showed Ida near or at major hurricane intensity before landfall

First forecast:
30 to 95 kt in 72 h

Timeline: 3 Days Before Landfall - First Advisory



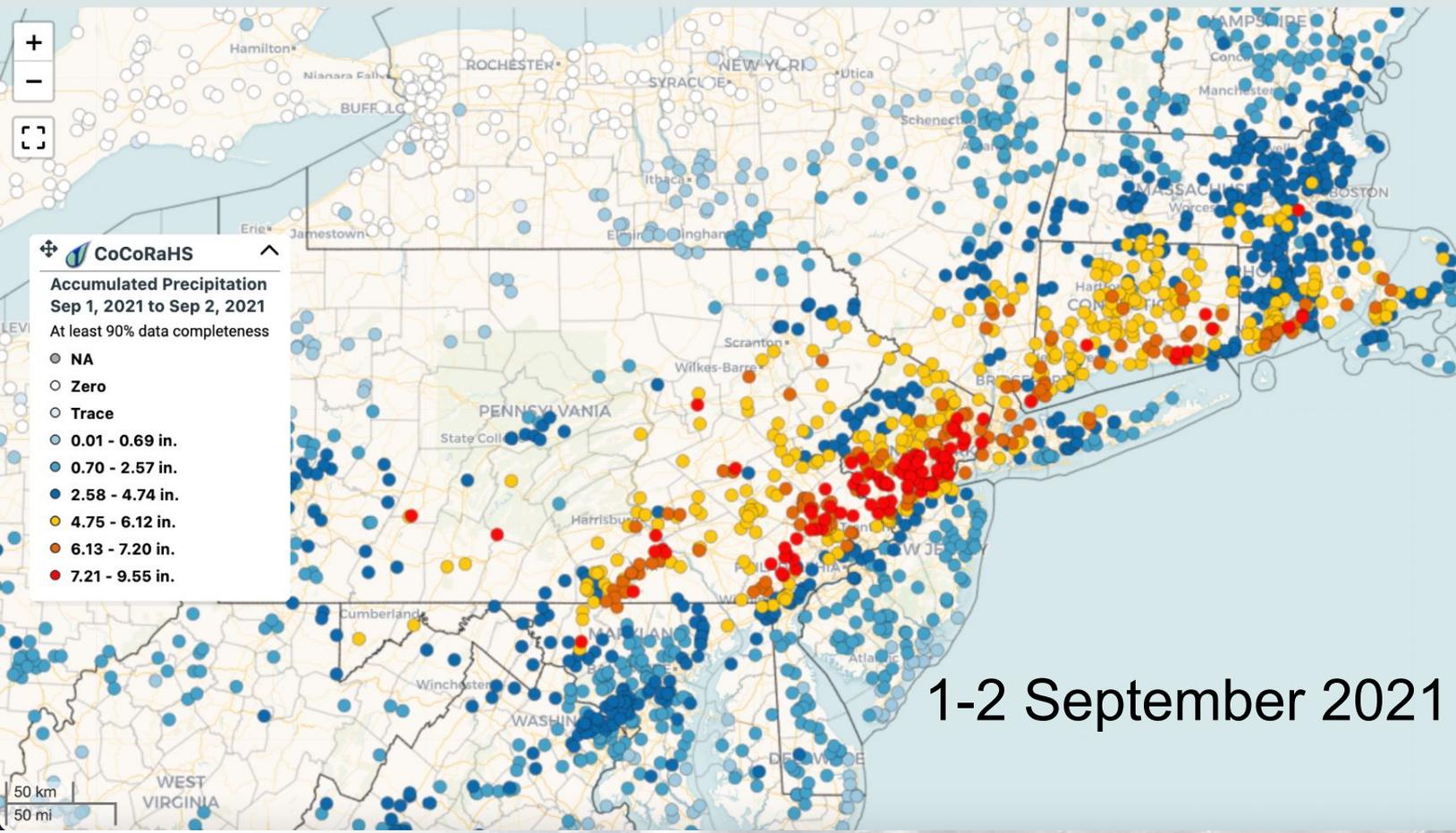
Intensity Guidance from First NHC Advisory

Explicit forecast of rapid intensification (30-kt or greater increase in winds) between 48 and 72 h

Forecast at the upper end of the intensity guidance

One of the most aggressive initial intensity forecasts NHC has ever made (30-kt TD to 95-kt hurricane in 72 h)

Challenges - Inland Flooding



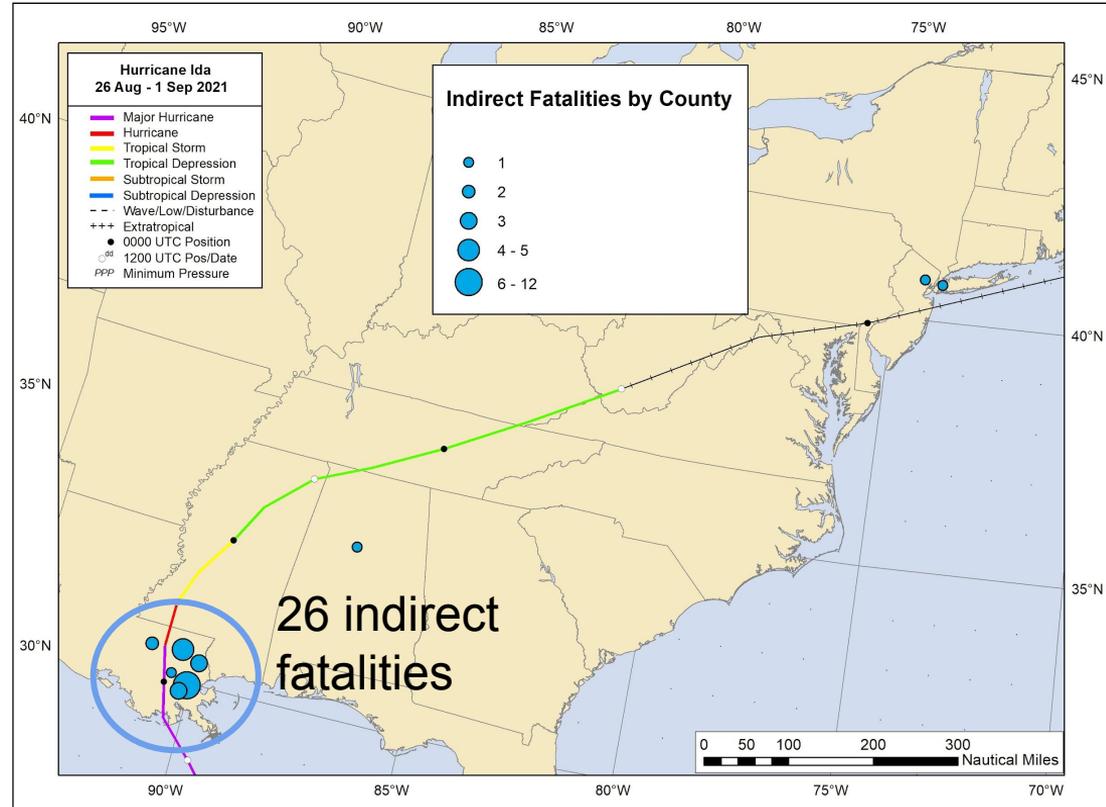
1-2 September 2021 rainfall

Challenges - Indirect Fatalities

Indirect fatalities in the hardest hit areas in the days/weeks following landfall

Large number of indirect fatalities in Louisiana (26) compared to direct fatalities (4)

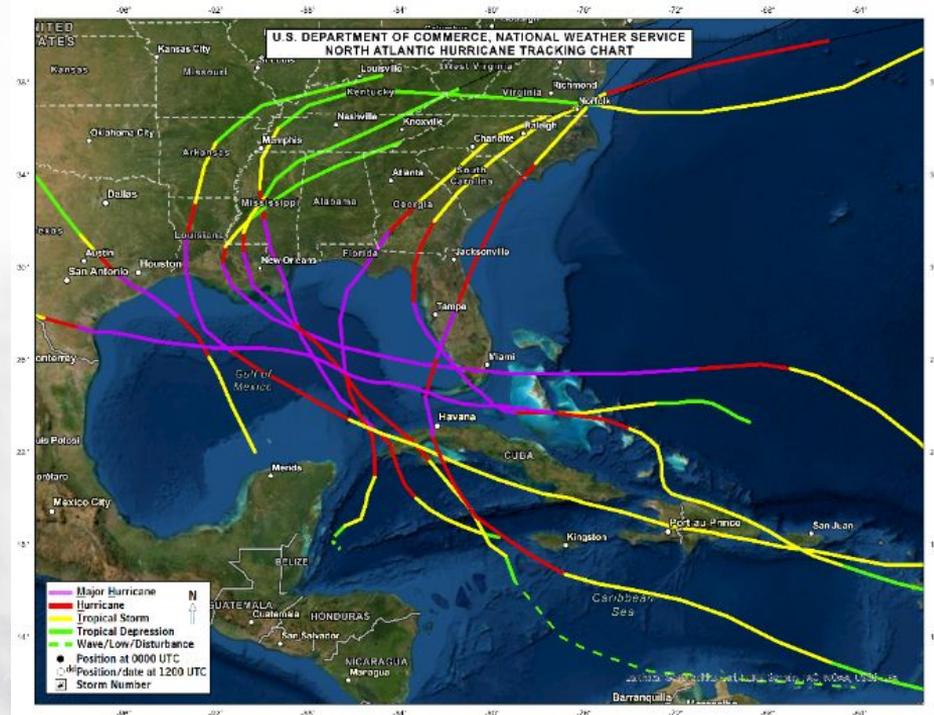
Most were due to heat, medical issues, and carbon monoxide poisoning



Challenges - Short Lead Time Events

Of the 9 strongest hurricanes that have made landfall in the continental U.S., only 3 existed as tropical depressions 5 days prior to landfall

Includes Michael, Laura, and Ida

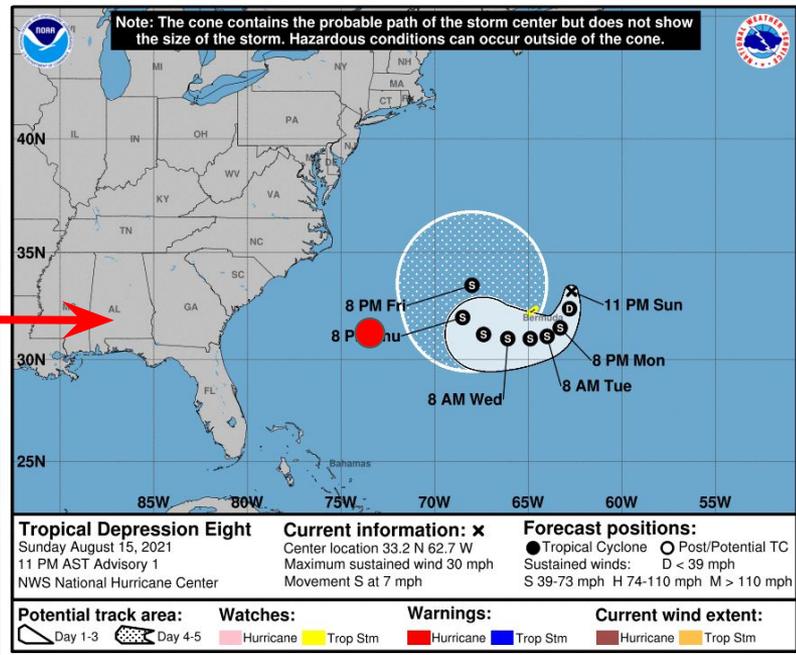
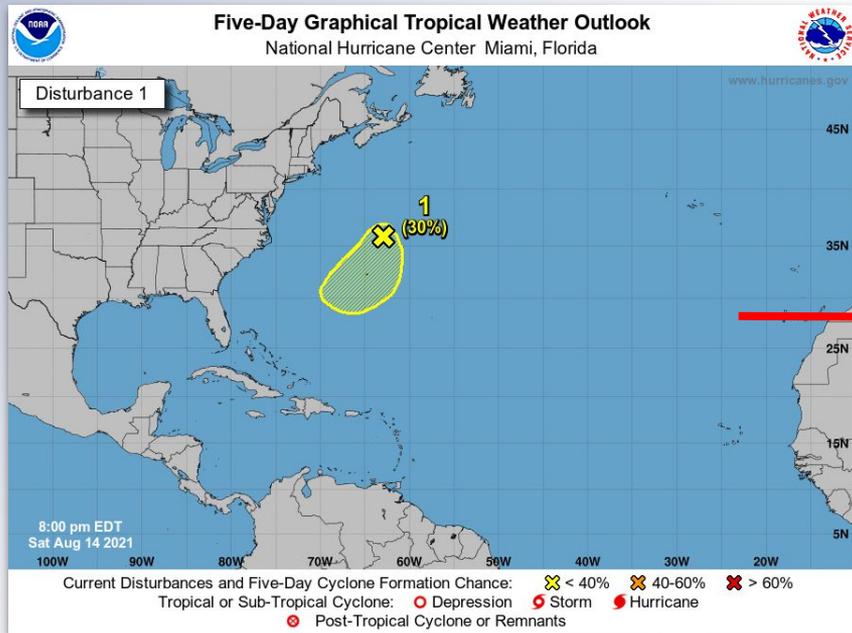


Analysis Challenges

Diminishing coverage and quality LEO satellite data

- Several microwave imagers have gone offline in recent years, including most recently WindSat (2020) and DMSP F-15 (2021)
- Loss of Metop-A (ASCAT-A), resulting in reduced ocean winds coverage
- Current microwave imagers for TC analysis include GPM, AMSR-2 on GCOM-W1, DMSP F-16, F-17, and F-18
 - All at or beyond planned mission life this year
 - Only GPM and AMSR-2 offer high-resolution 36-37-GHz channel imagery, which offers the best look at the low-level rainband and inner-core structure
- Future planned launches: first DMSP follow on (WSF M-1) is scheduled for 2023, METOP-Second Generation ~ 2023

Forecast Challenges - Henri Genesis

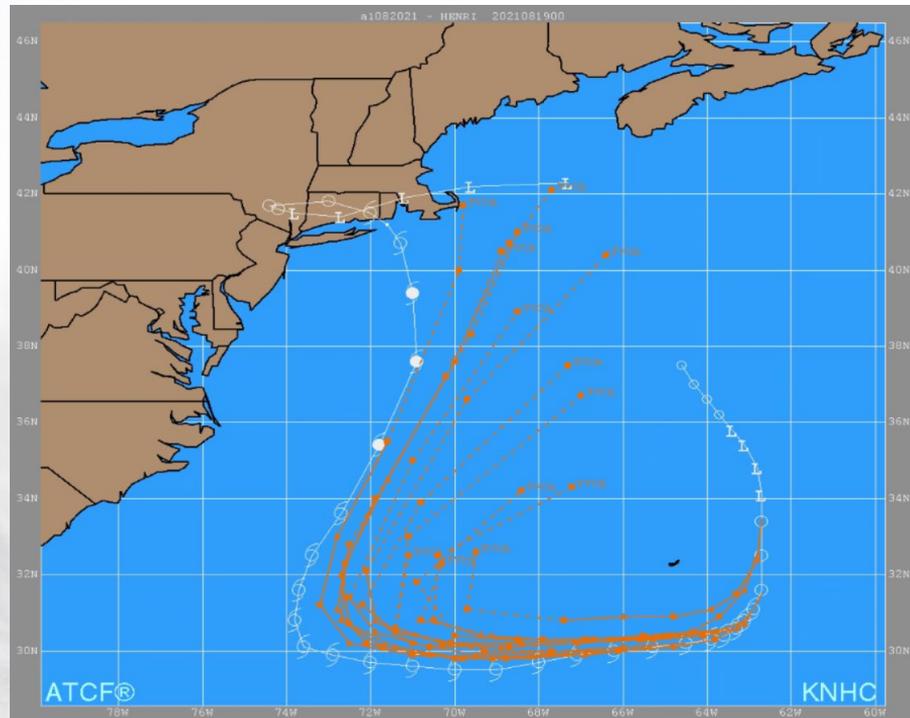


27 h lead time from first TWO

- Henri's initial track forecast was also a challenge given poor representation of the system in NWP guidance (see 5-day verification dot outside of cone)

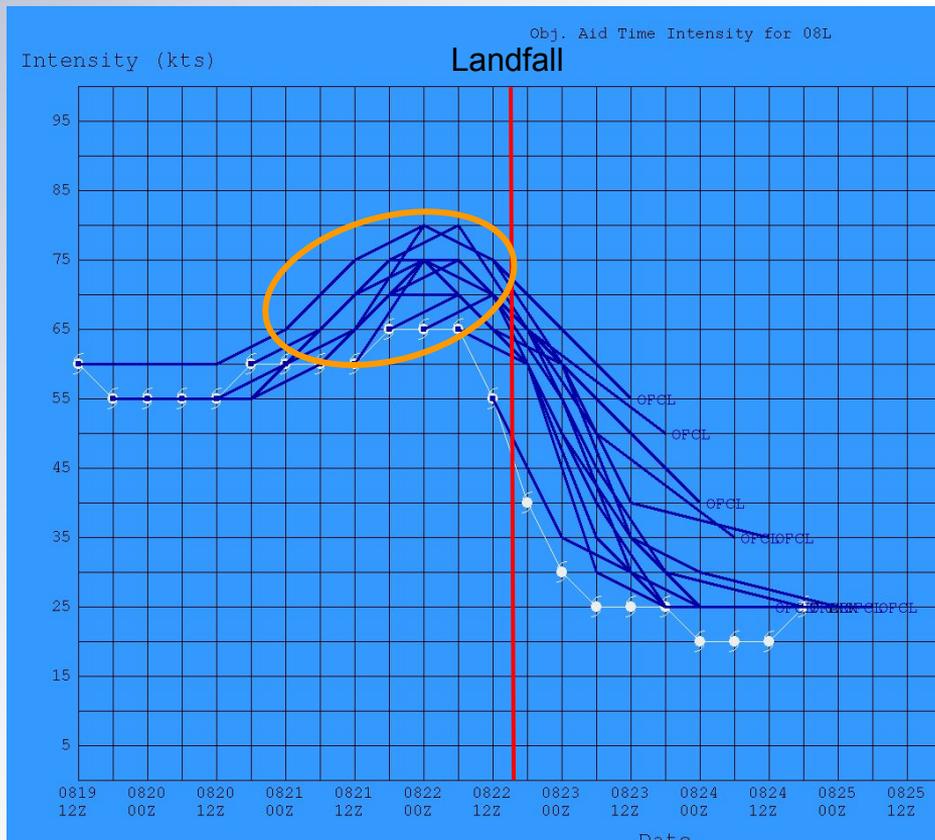
Forecast Challenges - Henri Track Guidance

Early track guidance significantly biased right of Henri's eventual track, and did not capture threat of impacts in the northeastern U.S.



TVCA multi-model consensus forecasts for Henri
00Z 8/16 through 00Z 8/19

Forecast Challenges - Henri Intensity Forecasts

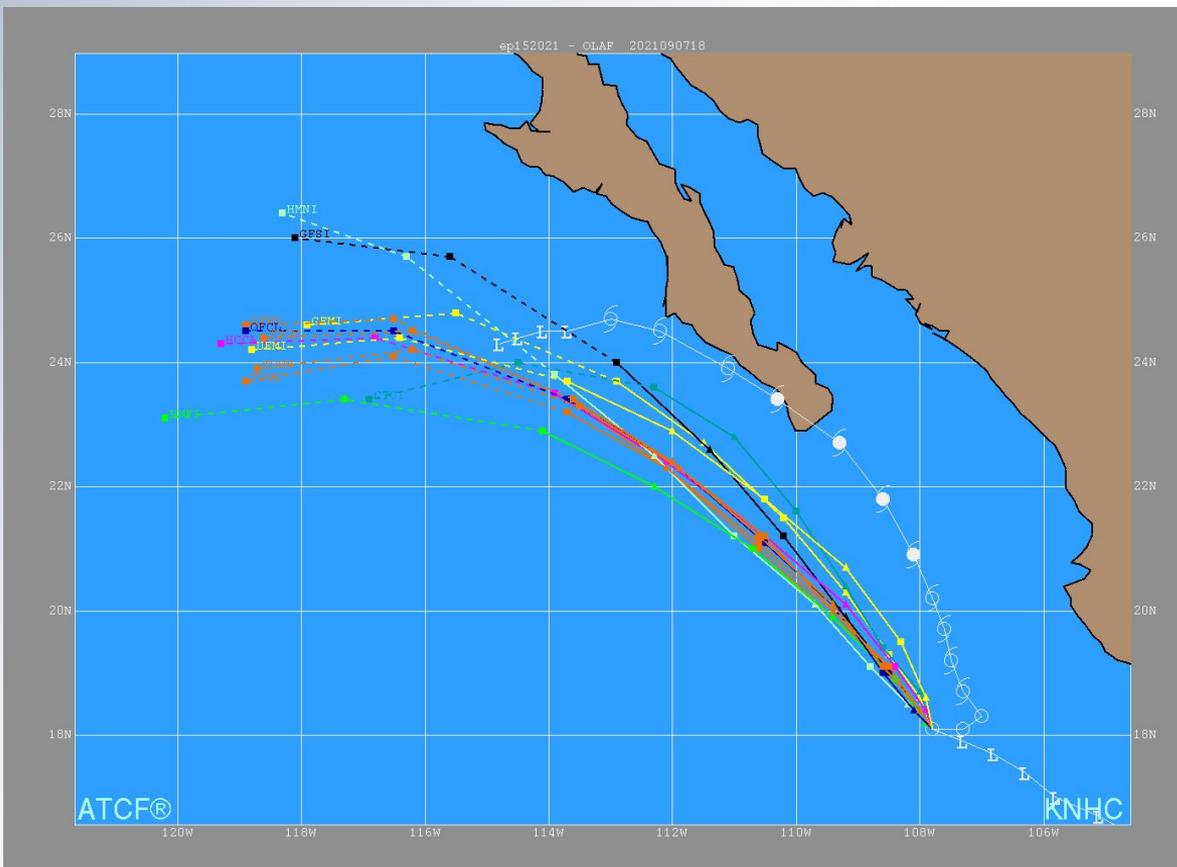


NHC intensity forecasts for Henri starting at 12Z 19 August

Intensity at landfall dependent on how much strengthening occurred on 21 August and when weakening would begin

Henri did not strengthen as much as forecast and made landfall as a 50-kt TS

Forecast Challenges - Olaf Track Guidance



All track guidance from the initial forecast cycle for Olaf showed the center passing well offshore of Baja California

48-h NHC track error was 114 n mi

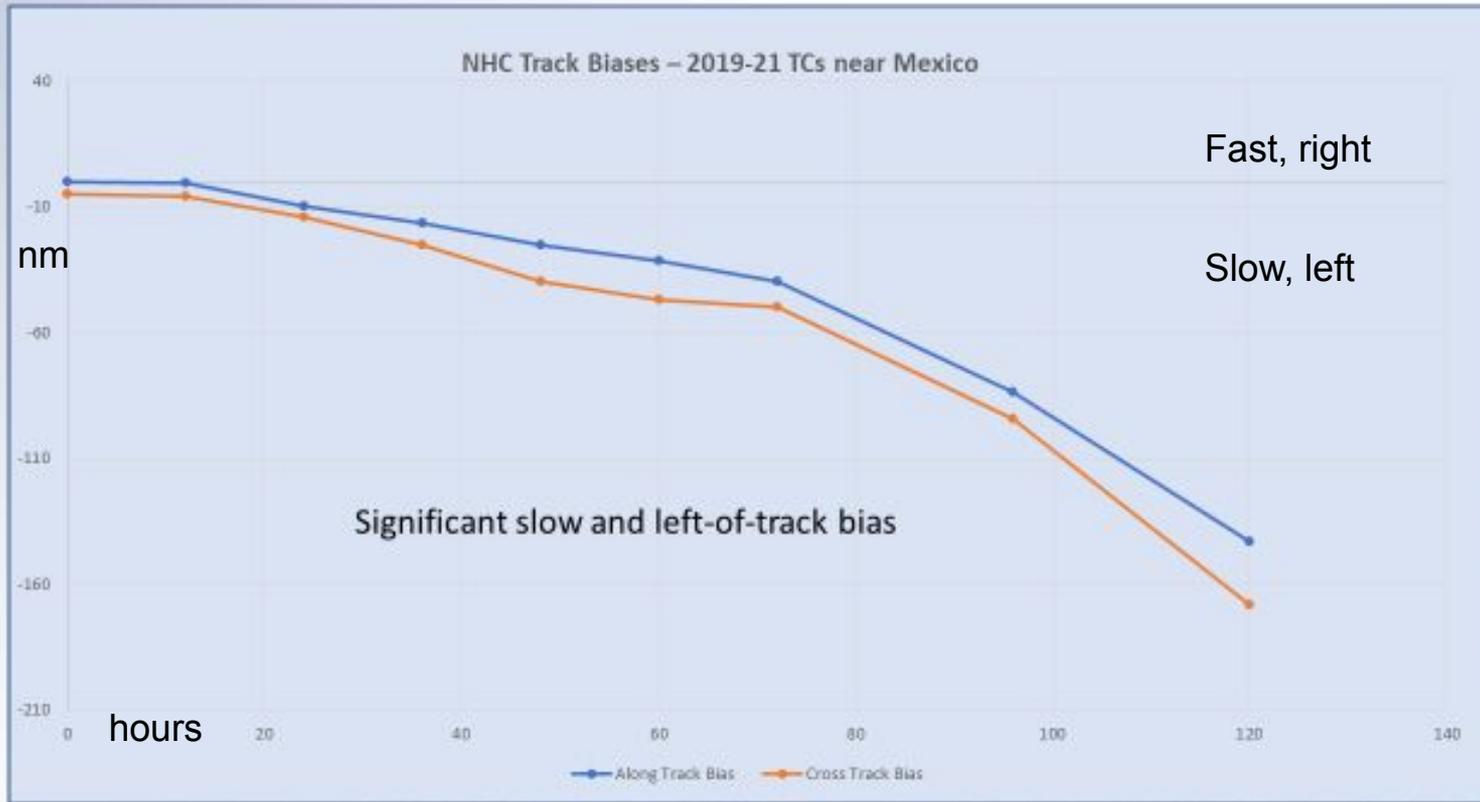
Average 2016-2020
48-h NHC track error is 54.6 n mi

Forecast Challenges - Nora Track Forecasts



Hurricane Warning wasn't issued until 06Z 8/28, only ~18 h before landfall

NHC Track Biases near Mexico, 2019-2021



-Really need to understand this problem! A tough situation for a warning agency

Summary

- Another very impactful season amid ongoing COVID pandemic
 - 2020-2021: 19 U.S. TC landfalls, including 8 hurricanes and 2 category 4 landfalls in Louisiana
- Improvements in forecasting rapid intensification
 - Challenges remain in response to short-fuse rapidly intensifying hurricane threats
- Minimal storm surge fatalities, but more work needed to address fatalities well inland from freshwater flooding
- Increased emphasis on raising awareness of risk of indirect fatalities in hard hit areas